PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : G08B 13/24, G01V 3/08, H04B 1/59, G01S 13/80, G07C 11/00, G06K 19/06, G01B 7/00

A1

(11) International Publication Number: WO 93/14478

(43) International Publication Date: 22 July 1993 (22.07.93)

(21) International Application Number: PCT/SE93/00036

(22) International Filing Date: 20 January 1993 (20.01.93)

(30) Priority data:
9200145-2 20 January 1992 (20.01.92) SE

(71) Applicant *(for all designated States except US):* RSO CORPORATION N.V. [NL/NL]; Abraham de Veerstraat 7, P.O. Box 840, Curaçao (AN).

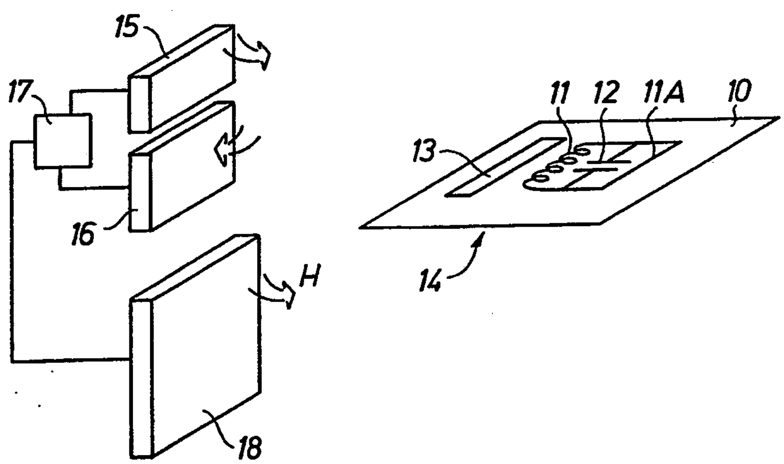
(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : TYRÉN, Carl [SE/FR]; 12, boulevard Albert-1er, F-06600 Antibes (FR). PERSSON, Leif [SE/SE]; Glasförgyllaren 51, S-245 00 Staffanstorp (SE).

(74) Agents: STRÖM, Tore et al.; Ström & Gulliksson AB, P.O. Box 4188, S-203 13 Malmö (SE).

(81) Designated States: AT, AU, BB, BG, BR, CA, CH, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, LK, LU, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SK, UA, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.
In English translation (filed in Swedish).

(54) Title: METHODS AND DEVICE FOR REMOTE SENSING OF OBJECTS



(57) Abstract

The invention relates to a method and a device for remote sensing of objects, said method including the steps of marking said objects with at least one label (10) comprising at least one electrical resonant circuit (14) having an induction means (11) and a capacitor means (12), exciting said resonant circuit (14) to resonance at a resonant frequency, and detecting said resonant frequency of said resonant circuit (14) by the electromagnetic energy transmitted from said resonant circuit (14). An element (13) of a magnetic material having a varying permeability is coupled inductively to said induction element (11). The resonant frequency of said resonant circuit (14) is affected by the permeability of said element (13) of magnetic material, and said element (13) of magnetic material is exposed to an external and spacially heterogenous magnetic bias field through which the permeability of said element (13) of magnetic material is controlled. The invention relates also to methods for coding labels and for noise suppression of signals received from said labels.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FR	France	MR	Mauritania
AU	Australia	GA	Gabon	MW	Malawi
BB	Barbados	GB	United Kingdom	NL	Netherlands
BE	Belgium	GN	Guinea	NO	Norway
BF	Burkina Faso	GR	Greece	NZ	New Zealand
BG	Bulgaria	HU	Hungary	PL	Poland
BJ	Benin	IE	Ireland	PT	Portugal
BR	Brazil	IT	Italy	RO	Romania
CA	Canada	JP	Japan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo	KR	Republic of Korea	SE	Sweden
CH	Switzerland	KZ	Kazakhstan	SK	Slovak Republic
CI	Côte d'Ivoire	LI	Liechtenstein	SN	Senegal
CM	Cameroon	LK	Sri Lanka	SU	Soviet Union
CS	Czechoslovakia	LU	Luxembourg	TD	Chad
CZ	Czech Republic	MC	Monaco	TG	Togo
DE	Germany	MG	Madagascar	UA	Ukraine
DK	Denmark	ML	Mali	US	United States of America
ES	Spain	MN	Mongolia	VN	Viet Nam
FI	Finland				

WEST

METHOD AND DEVICE FOR REMOTE SENSING OF OBJECTS

The invention relates to a method and a device for remote sensing of objects. Within trade and industry the interest in non-optical and non-contact sensing of objects have increased lately. In stores and superstores it is interesting to read price labels and similar elements, and within the industry it is desirable to read identification labels in industrial materials flows. A plurality of non-optical and non-contact principles of identification of labels are used at present. Most common is perhaps anti-theft labels in shops.

In a commonly used embodiment in trading labels are used which are provided with a resonant circuit comprising a capacitive and an inductive element. Said resonant circuit can be forced to resonance by applying an electromagnetic signal having a defined energy content at the resonant frequency to said label in an interrogation zone normally provided at the exit of the shop. A detection device detecting signals from said resonant circuit at the resonant frequency produces an alarm if a label provided with an "activated" resonant circuit enters into said interrogation zone. A practical embodiment of a resonant circuit intended for this purpose is disclosed in US,A,4 578 654. A complete system includes also a device for "deactivating" said label which is done on payment of the merchandise on which the label is attached to.

A problem of all previously known labels used in a purpose of limiting pilferage is a lack of ability of individually identifying each label when a plurality of labels is present simultaneously in said interrogation zone. For the purpose mentioned the problem is not relevant because an alarm should be delivered independently if one or a plurality of labels having an "activated" resonant circuit enters into said interrogation zone and is detected.

The method according to the present invention is based on the fact that certain magnetic and mechanical properties of elements shaped as tapes, wires or strips of amorphous materials are changed when the elements are exposed to a magnetic field, a so called bias field. The position/direction of an element is for instance related to the magnetic field in the longitudinal or axial direction of the amorphous element, and the mechanical resonant frequency of the element is a measure of the position/-direction of the element. Corresponding conditions apply for a component comprising an amorphous element which is magnetically coupled to an inductive element in turn included in an electrical resonant circuit. When the magnetic field is changed the magnetic properties of the amorphous element are changed, and by that the inductance of said inductive element is changed. Then also the resonant frequency of the electrical resonant circuit is changed.

Also other materials than amorphous materials can be used according to the invention. The essential property of the material is that the characteristics thereof, for instance magnetic or elastic properties, are effected by magnetic fields. The influence must have such an extent that the change of properties is measurable by remote detecting, i.e. without establishment of a physical contact with said elements. It is also possible to use other materials, the electric or magnetic properties thereof being changed by an external magnetic field. An example is a material that is magnetoresistive, that is the electrical conductivity thereof being changed depending on a magnetic field, and a magnetooptical material, that is a material the light conducting ability thereof being changed depending on an applied magnetic field. For materials of said latter type a phenomenon referred to as the FARADY EFFECT is utilized, that is that the plane of oscillation

of polarized light is pivoted, the pivoting angle being proportional to the magnetic field strength, or the phenomenon referred to as the KERR EFFECT, according to which a similar effect appears in some materials under influence of an electrical field.

The resonant frequency of an amorphous element showing a comparatively large magnetomechanical coupling is changed by the so called delta-E-effect with the magnetic flux intensity along the main direction of the element. If said magnetic flux intensity is changed as a function of the position/direction of said amorphous element the resonant frequency of said amorphous element will then be a function of the position/direction of said element. It is an advantage that the measuring information is produced as a frequency value because such a value is highly immune to interferences. Furthermore, a mix of information from a plurality of gauges, each of which operates at a separate frequency band, can be transferred together at one channel of information.

To increase the measuring precision it is possible also to utilize methods according to which a plurality of amorphous elements simultaneously are located in a measuring body. In such a case it is appropriate also to record beat frequencies and sum frequencies. By utilizing such differential measuring methods error sources such as for instance system deviation depending on temperature, material properties, changes of field, etc, can be eliminated.

It should be noted that the efficient magnetic field along the axial direction of said amorphous element not necessarily is equal to the projection of the total field vector along the amorphous element. By the flux conductive ability of said amorphous element and the geometry thereof there could be a deviation from pure projection. However, the relationship can always be determined and could still

form the bases of recording ofjects that are provided with amorphous elements.

By using tapes of amorphous magnetoelastic alloys a theftprotection label it is possible also to use other physical effects and conditions. A theft protection label of this type will include one or a plurality of such tapes. Said tapes have a high magnetomechanical coupling which means among other things that the tapes can be made to oscillate mechanically by applying magnetic energy. During the mechanical oscillation also the magnetic properties change, which can be recorded by a detecting coil or similar device. An essential factor of the resonant frequency of the tape is the module of elasticity. Since the module of elasticity of the amorphous tapes used depends on external magnetic fields it is possible by varying such an external magnet field to change the resonant frequency of the tape. By providing a magnetic element that can be magnetized and demagnetized adjacent to a tape of an amorpohous material the tape can be given two resonant frequencies, a first when the magnetic element is magnetized and a second when it is demagnetized. Such a system is disclosed in EP 0096182. In this type of systems it is necessary that the tapes are arranged to be moved freely in such a way that the mechanical movement during oscillation is not prevented or affected to such a level when a safe detection is in danger. The excitation of the tapes to oscillation as well as the detection of the resonant frequency is made through magnetic fields which highly limits the range of operation, in the excitation as well as during detection.

A more developed system for remote sensing of objects is disclosed in EP 00330656. Instead of an element of a magnetic material that can be magnetized and demagnetized, respectively, to set the resonant frequency of the tape a spatially heterogenious magnetic field in the interrogation

OK

WEST

zone is used according to EP 00330656. In that way a plurality of labels located within different subareas of said interrogation zone in which the magnetic field is directed differently or is of a different strength can be sensed and identified even if a plurality of labels are provided with identical sets of tapes. However, problems and drawbacks of excitation and detection by means of magnetic fields still remain. Also in this type of labels it is important that the tapes are arranged on the label to be moved freely. Thus, said labels have to be produced, arranged on the objects and be handled in a proper way so that the movability of the tapes is not affected.

An object of the method and device defined in the introductory part of claim 1 and 3, respectively, is to overcome the drawbacks indicated above by using an electric resonant circuit, and it is also an object to overcome problems and drawbacks of detection devices including tapes of a material having a high magnetomechanical coupling. Said objects have been achieved according to the invention by the features of the characterizing part of claim 1 and 3, respectively.

Developments of the invention with regard to coding of the identity of said labels, and with regard to interference suppression of received signals are shown in the dependent claims.

The invention will now be described in more detail by means of embodiments, reference being made to the accompanying drawings in which

FIG 1 is a schematic view showing the method and the device according to the invention,

FIG 2A shows a first alternative embodiment of a resonant circuit to be used according to the invention,

FIG 2B shows a second alternative embodiment having double resonant circuits to be used according to the invention,

FIG 3 is a diagram showing how the magnetizing field strength depends on the position in an interrogation zone used according to the inventioin,

FIG 4 is a diagram showing the relative permeability of a tape made of a magnetic material in relation to the magnetizing field strength in the interrogation zone,

FIG 5 is a schematic view showing a combined transmitting and receiving antenna to be used according to the method of the invention,

FIG 6 is a schematic view showing a further development of a device for detecting objects,

FIG 7 shows schematically in a perspective view an interrogation zone with biasing coils,

FIG 8 is a top view of the device of FIG 7,

FIG 9 is a diagram showing a combination of resonant circuits having different resonant frequencies,

FIG 10 shows schematically a coding method according to a development of the invention,

FIG 11 shows schematically an alternative coding embodiment according to a development of the invention,

FIG 12 shows a practical embodiment for the method of coding according to FIG 10,

FIG 13 shows a practical embodiment for a method of coding according to FIG 11, and

FIG 14 and FIG 15 are graphical representations showing characteristics of the material that can be used according to the invention.

FIG 1 shows a label 10 which is provided with an electric resonant circuit 14. A label refers according to the invention to any elements that can be mounted on or during production be embedded in objects that can be remotely detected. The resonant circuit can for instance be embedded in a wall or a surface of the object such as a spine, embedded in a cavity in a piece of furniture, molded into a plastic part, or in a similar manner.

The electrical resonant circuit 14, comprises an inductive element 11 and a capacitive element 12, and has through said elements an antenna function. In the embodiment shown in FIG 1 there is also provided a further conductor 11a. Said conductor 11a is connected in parallel with said capacitive element 12, in this case formed as a capacitor, and constitutes a part of said inductive element. Said inductive element 11 including a coil is conductively coupled to an element 13 made of a magnetic material. Said element 13 is arranged adjacent to or within said coil. Said element 13 is preferably made of a tape of an amorphous alloy. Said element 13 of magnetic material possesses according to the invention such a property that the permeability thereof will vary by the influence of an external magnetic field. By the inductive coupling between said element 13 and said coil 11 the resonant frequency of said resonant circuit 14 depends directly on the magnetic properties, that is the permeability of said element 13.

To excite said resonant circuit 14 to oscillation at the resonant frequency of said resonant circuit, which falls within a radio frequency interval, an electrical excitation means 15 is provided. Preferably said excitation means 15 comprises an electromagnetic antenna which is connected to a control unit 17 including a transmitting unit not shown here. An embodiment of an antenna 15 is shows in FIG 5. To said control unit 17 there is connected also a detecting means 16 which preferably also includes an antenna. To allow a plurality of identical labels having identical resonant circuits 14 to be detected, identified and recorded when they simultaneously are located in an interrogation zone 33 there is provided a means 18 for producing a magnetic field. Said means 18 is operatively connected to said control unit 17 and produced a spatially heterogenous magnet field varying in strength and/or direction in each location or subvolume of said interroga-

WEST

tion zone. The magnetic field generated provides a spatial reference system that can be used in different ways according to the invention. A difference of magnetic field between adjacent location or subareas within said interrogation zone will affect magnetically said magnetic elements 13 of each of said resonant circuits so that the relative permeability thereof will be changed differently. In that way also the property of the inductive elements of said resonant circuits are affected differently resulting in different offset of the resonant frequency of said resonant circuits. Said offset depends on the characteristica of the magnetic field in the location of said label and said magnetic element, and also on the orientation of the element in space.

FIG 2A shows an alternative embodiment of said resonant circuit. The difference compared to resonant circuit shown in FIG 1 is that said conductor 11a has been excluded.

FIG 2B shows an alternative embodiment including double resonant circuits 14 and 14′ which are connected to a common element 13 made of a magnetic material. The resonant frequencies of said resonant circuits 14 and 14′ can be made different by applying to the coil 11′ and the capacitor 12′ of said second resonant circuit 14′ different properties than corresponding components of said first resonant circuit 14. Also other alternative configuration of an inductive element 11, a capacitive element 12, and elements 13 made of magnetic materials are possible within the scope of the invention. Other configuration can be chosen also to improve other electrical properties of the resonant circuit such as Q value, antenna properties etc.

The physical background explaining why it is possible according to the invention to identify a plurality of identical labels within the interrogation zone will now be described with reference to FIG 3 and FIG 4. Said means 18

for generating a magnetic field and described in connection with FIG 1 generates a spatially heterogenous magnetic field in said interrogation zone. Said magnetic field in the interrogation zone will vary with regard to strength and/or direction in different locations within the interrogation zone. This is illustrated schematically in FIG 3 showing the variation of the magnetizing field strength in different locations, for instance having different X coordinates.

The amorphous material of the tapes that preferably are used according to the invention possess such a property that the relative permeability depends on the magnetic field strength H and accordingly on the magnetic field B in the interrogation zone.

FIG 4 is a graphical representation showing this relation. The amorphous material has a very high magneto-mechanical coupling and thus the magnetic properties of the amorphous material are affected also by the mechanical conditions that the tapes of amorphous material are exposed to. The upper diagram line in FIG 4 marked χ^{σ} shows how the relative permeability depends on the magnetic field strength when the tape can be moved freely and is allowed to oscillate also mechanically. The lower diagram line marked $\chi\epsilon$ shows the dependence of the relative permeability on the magnet field strength when the tape of amorphous material is fixedly attached and cannot oscillate mechanically. According to the invention anyone of the conditions indicated can be employed and it is possible also to utilize "double" properties either as a further coding of a label or for setting said label from an "activated" condition in which said label in a pricing system indicates a merchandise that has not been paid for, and a "deactivated" condition in which said label indicates a merchandise that has been paid for. As the magnetic field in the interrogation zone will vary in all locations or subvolumes

all magnetic elements located in said interrogation zone will be exposed to a magnetic field of different strength or direction. In that way the relative permeability of said magnetic elements 13 will have different values depending on the position and orientation of the element in the interrogation zone, and this will in turn change the electrical properties and the resonant frequency of said resonant circuit 14. For instance is $L=f(\mu_r)$, that is the induction depends on the relative permeability.

In a basic embodiment each of the resonant circuits of all labels has a unique resonant frequency which will identify the label in a basic condition, that is in a condition with a known and stable magnetic field. Then when the label is disposed in the interrogation zone the resonant frequency of the resonant circuit will be offset. Different resonant frequencies and maximum variations allowed in the magnetic field from said device 18 are chosen in such a way that the resonant circuits and thus also the labels of different objects cannot be mixed up by the detecting system 18.

In further developed embodiments a plurality of elements 13 made of magnetic material, are combined to make the frequency dependence of the resonant circuit of the external magnetic field more complex and hard to copy.

Tapes made of amorphous material are extremely direction sensitive, that is their sensitivity to external influence in form of external magnetic fields, traction and compression strain force etc. varies highly with the orientation in relation to the direction in which the external force is supplied. Such a condition is used already in the basic embodiment of a label according to the invention by that a plurality of identical labels that are oriented in different directions readily can be separated by the detection system even if they are disposed in the absolute vicinity to each other. In a further developed

embodiment of a label according to the invention a plurality of identical tapes of amorphous material or tapes formed in different ways are arranged on top of each other but pivoted in relation to each other. This will allow an extremely extensive and complex coding of a label in a very compact embodiment. An alternative coding method is described below with reference to FIG 10. To further increase the safety it is appropriate also to excecute a plurality of consecutive detecting steps having different sequences of heterogenous magnetic bias fields.

The electrical excitation means 15 as well as the detection means 16 comprise some kind of antenna for transmitting and receiving, respectively, electromagnetic radiation in form av radio waves. An example of a combined transmitter and receiver antenna is shown in FIG 5. A transmitting antenna 19 which is operatively connected to said excitation means 15 and formed as a single loop of rectangular shape encloses a receiver antenna 20 shaped as an eight and operating as a balanced frame antenna. Said receiver antenna 20 is operatively connected to said detecting means 16. The embodiment of an antenna arrangement shown in FIG 5 is preferred because transmitting and receiving at the same frequency is facilitated. Also other more or less conventionally formed antenna systems can be used within the scope of the present invention. The resonant circuit 14 emits energy also within other frequency intervals than the resonant frequency, for instance harmonics of the resonant frequency, and thus it is appropriate in certain applications to excite said resonant circuits at one frequency and to detect oscillations at another frequency.

FIG 11 shows an example of the arrangement of said interrogation zone with the means for generating a magnetic field. In the shown embodiment the heterogenous magnetic field in said interrogation zone 33 is generated by four

coils 29,30,31,32 which are arranged in pairs in right angles on different non-opposing sides of the interrogation zone 33. The orientation of the coils are shown also in FIG 8 which is a top view of the interrogation zone 33 with said coils 29,30,31,32 shown schematically.

On large demands of miniaturization of the label thin film technique or similar techniques can be used to produce the complete label including the capacitive element 12 and the inductive element 11 and other conductors and antenna function included therein. Also coil elements and capacitors produced as conventional elements can be used in some applications.

In an alternative embodiment said inductive element and said magnetic element are connected into a so called "cloth inductor" in which said elements are combined into a web like structure. This embodiment will provide a high magnetic coupling factor between said magnetic element and said inductive element.

In an application for pricing labels each label is provided with n resonant circuits having n different resonant frequences. The diagram of FIG 9 shows detected resonant frequences $f_1 \ldots f_n$ from one of said labels. Each resonant frequency defines one "bit" in a code of an item. Existance of a specifid resonant frequency in the detected signal will indicate that the corresponding "bit" is set. The offset of the resonant frequency of all resonant circuits depending on the bias field is known and therefore all resonant circuits that are exposed to one and the same bias field can be related to a specific label. Then the label is identified by the combination of resonant circuits, that is of the resonant frequences, giving the code of the item. The resonant frequences will vary or be offset within the dashed area in FIG 9 for each frequency.

The method and the device according to the invention are very suitable to be used in different applications in

connections with marking, for instance price marking in trade, marking of products within manufacturing industry or transport industry, in coding of credit cards, and also in "seal marking" of for instance documents, tickets, etc. In the latter application the previously described embodiment, having a plurality of bands of amorphous material together forming a more "complex" transfer function of permeability and external magnetic field, can be used.

The method and the device according to the invention can be applied also in determining position and/or orientation. In such an application the magnetic field generated in said interrogation zone is known in detail in every location with any desired resolution. When a measuring object including the resonance circuit according to the invention is entered into said interrogation zone and the resonance frequency thereof is detected by the detecting means 16 the deviation of frequency from a nominal resonance frequency of the circuit is an exact indication of the position of the object in the interrogation zone. A corresponding method can be applied also for direct distance measuring. To determine only the orientation a completely homogeneous bias field can be used.

The method and device according to the invention can be used also in other applications and at other frequences not disclosed here. At lower frequences than radio frequences the coupling between the label and the transmitter/receiver is made mostly on the basis of induction. The embodiments of resonant circuits and control and detection systems disclosed above should be regarded only as examples, a plurality of other embodiments are possible within the scope of the invention as defined in the accompanying claims.

At least two properties of tapes, wires and similar elements of amorphous material are affected in a basic way by a surrounding magnetic field. A first property to be

affected is the elastic properties of the element, and in that case the so called delta-E effect is used. Variations of elastic properties affect directly other properties of the element, for instance the mechanical resonant frequency of the element. The mechanical resonant frequency can be detected as a magnetic signal, for instance by a detecting coil because the magnetomechanical coupling of said elment is very large.

The detected signal includes besides the desired signal also different interference signals appearing around the measuring site. To be able to use the detected signals as desired when identifying elements any unwanted signals have to be filtered out or suppressed.

To accomplish a suppression or filtering the following measures can be taken. When an element is exposed to a varying magnet field strength the resonant frequency of the element will vary according to the variation of the field strength. FIG 14 is a graphical representation showing delta-E of an element as a function of a magnetic field strength H. When the magnetic field strength is varied according to a first function the delta-E of the element will vary according to a second function that can be associated to or be identical with said first function. By suppressing all detected signals that are not associated in this way to said first function it is ensured that only wanted signals are recorded and further processed.

FIG 15 shows correspondingly how a second property of an element is affected, namely the relative permeability μ_r. Also μ_r is a function of the magnetic field strength H. Any influence on said relative permeability is suitably detected by coupling said element magnetically to an inductive element included in an electric resonant circuit which includes also a capacitor. When said resonant circuit is excited to oscillate it will transmit electromagnetic radiation which can be recorded by means corresponding to

WEST

conventional radio receivers. The frequency of the electromagnetic radion is then affected by the surrounding magnetic field strength H.

Interference signals appear also in this type of detecting, and it is highly desirable to suppress interference signals also in this type of detecting. This is conveniently done according to a method as indicated above.

FIG 6 shows an embodiment of a device according to the invention. In this embodiment said means 18 for generating a magnetic field includes a modulator 25 which modulates the magnetic field generated by said coils 29,30,31,32 in accordance with a predetermined function. Said coils 29,30,31,32 are fed by a current generating means 26 through controllable amplifiers 27. Said current generating means 26 and said modulator 25 are controlled by said control unit 17, which is operatively connected thereto.

OK

The device comprises also a transmitter antenna 19 and a receiver antenna 20 formed in accordance with the embodiment shown in FIG 5. One label 10 is located in the interrogation zone. The input signal from said receiver antenna 20 is amplified in a first amplifier step 21 and then in a second amplifier step 22 before being fed into a PLL-circuit (Phase Locked Loop) 23. A frequency output of said PLL circuit 23 is connected to said transmitter antenna 19 through an amplifier 24. An internal, frequency adjusting signal in said PLL-circuit is tapped and fed to a comparator 34. Said tapped signal referred to as V_{demod} forms a demodulated signal corresponding to the signal generated in a modulating unit 25 in said means 18 for generating a magnetic field. When the bias signal is not modulated said signal of the PLL-circuit is a measure of the present non-modulated resonant frequency. Also the signal generated in said modulating unit 25 is fed to said comparator 34 so as to compare the controlling modulating

signal from said modulator unit 25 to the demodulating signal from said PLL-circuit 23. The result of the comparison is preferably used to filter out any disturbances appearing in the interrogation zone and being received together with the wanted signal.

To ensure that a received signal originates from an element to be remotely detected it is possible also to sample the received signal that originates from an amorphous element. In a basic embodiment of such a method the sampled signal defining a received frequency is controlled to vary in time. During correct conditions the received frequency is the resonant frequency of an element. If this is the case the sampled signal is regarded to be a wanted signal and said signal is processed as indicated above to determine any existance of a specific amorphous element on a label or similar device, and thereby to identify the label and the object on which the label is attached.

In further developed systems there is a digital signal processing of the sampled signal so as to determine the relation between the variation of the bias field and the variation of the sampled signal. Only if the relation meats predetermined standards the received sampled signal is passed on. The determination of the relation can be made for instance by dividing the received resonant frequency signal into Fourier-coefficients. When these are compared the accordance between the contolled signal and the received signal can be determined.

According to an alternative and basic embodiment there is instead made a filtering of the static part of the received frequency signal. If a varying part remains, that is if the frequency varies, this will be accepted as a confirmation of the signal originating from an element which has been affected by the bias field.

Different factors will affect the selection of decoding methods. One important factor is the environment with respect to interferences that exist in the detection volume.

The bias field can be adjusted with regard to the absolute value of the magnetic field strength and also with regard to the direction of the magnetic field strength.

A further method for ensuring that a received signal originates from an element to be remotely detected is based on producing distortion in a controlled and predetermined manner of the signal transmitted from the elment of amorphous material. Then only received signals that have been distorted in the predetermined way are used for determining existing resonant frequences.

The signal processing being made on a received signal to suppress unwanted signals is the same independant of the received signal being magnetic, when the magnetomechanical coupling of the amorphous element is used, or electromagnetic, when the influence of the element on an electric resonant circuit is used.

To provide a coding of labels allowing identification of a plurality of labels in a detection volume even if a plurality of identical labels is located in the volume at the same time at least three embodiments are possible. A first embodiment is similar to a type of binary coding. In a fixed set of elements shaped as tapes or wires of amorphous material elements may be present or be removed corresponding to 1 and 0 in a binary code. The number of tapes is also equal to the number of bit positions, and the tapes are all different. This would mean comparatively large costs for producing labels and will limit to some extent the total number of possible label identities.

In an alternative coding method a plurality of magnetic elements 13 are disposed "on top of" each other with an angular deviation and will each by the angular

WEST

position thereof constitute a "bit" or a code position. In the embodiment shown in FIG 10 the position system has the base 10 because each element can be set into one of ten angular orientation positions. Each element 13 is given a uniqe length/resonant frequency. When there are a plurality of labels at the same time in a detecting zone the detecting device will read code elements from a specific label as they are all located in one and the same coordinate position with different angular orientations in one and the same pivoting plane (if the label is plane). Different labels can be separated by different x,y,z-position and/or different "pivoting planes", which means that each label is individually detectable even if a plurality of identical labels are detected simultaneously.

A major advantage with the second coding method compared to the binary code indicated above with regard to read reliability is that the number of amorphous element in the second coding method is always constant (for a specific number interval or base) because the code information is in the signal relation, that is the frequency relation or angle between the different amorphous code elements, and not in the existance or non-existance of a specific amorphous element which is the case when the binary coded label is used. This would mean that the number of amorphous elements that is provided in each label is known, which is not the case in a binary coded label. Then the detecting system can control that all code elements have been recorded and can also determine if any label lacks any of the elements. This highly improves the validation process during detection.

Using such a coding method different detecting algorithms can be used. Thess can be divided into algorithms implying that the bias field used is known and mapped, and such algorithms that do not require knowledge of the characteristics of the magnetic field. Both methods

of detecting can be used according to the present invention.

According to a coding method the angles between the amorphous elements of the label are used to define the code position. Thus, each element can be set to represent any code value within a predetermined number interval. That means that the base can be considerably larger than two, for instance 30. When using the base 30 and on condition that a label comprises four coding elements plus a reference element it is possible to provide code values between 0 and 809999 using five tapes, and if binary code is used only values 0-31 can be utilized.

An algorithm for detecting labels having two refence elements and four coding elements will now be described. In the description below it is assumed that all tapes in a label have different length so as to be readily identified separately.

On condition that the local magnetic field distribution over a label is homogeneous the two reference elements will provide the angle and the absolute value of the magnetic field vector over said label in the plane of the label. The two right angle components of the bias field are determined by using the detected resonance frequency of the elements. The detected resonant frequency corresponds to the bias field along the longitudinal axes of the elements. Having knowledge about the effective value and the angle of the bias vector in the actual plane the angles of the code elements can be determined by utilizing the relation between detected frequency and magnetic field. This is done for each code element. The value of the bias vector along a code element divided with the value of the bias vector in the plane determined as indicated above will provide immediately, or indirectly as a result of influence of adjacent elements, through another function, the cosinus of the angle between a code element and the bias vector. As

the angle of the bias vector has been determined it is possible also to determine the angle of the code element and thus the code value set for the specific code element. The code value determined might be corrected with regard to influence from adjacent bands.

However, a problem still remains of relating signals from different elements to each label. However, it is possible to calculate all possible combinations of reference and code elements. Among these also the correct codes are included together with a large number of noise codes.

By providing a sequence of different bias field situations and calculating for each bias field situation all possible codes the correct codes will be repeated to a completely different extent than the noise codes. Only those codes that are "repeated" will then be accepted. It is obvious that when a large number of labels is located in the detection volume at the same time the number of possible codes will be extremely large. To facilitate the analysis of incomming signals it can be appropriate to divide the detection volume into a plurality of smaller subvolumes. Then the number of labels per volume will be lower and the algorith for analysis can be executed faster. It is possible also to eliminate a number of possible codes by certain modulation of the bias field and by using further logical functions.

In an alternative embodiment according to FIG %FIG of the coding method described above the possibility of remote detecting of the angle between elements is not used but instead the possibility of remote detecting of the relative distance between single elements is utilized. Such an alternative coding method corresponds to some extent to the commonly used pincode.

One example of such an embodiment comprises a label having a plurality of elements of different length arranged

in parallel on a distance ~~from a reference tape.~~ The distance from said reference tape to the actual distance of a specific element constitutes a code value of the element. To improve reading possibilities of a label of such a type it is appropriate to arrange also a second reference element on a distance from said first reference tape. All other elements are arranged between said reference elements. By using two reference elements it is possible when reading to determine the local field gradiant along the code elements and the label. Hereby it is possible to read in all regards the information of the label without knowing in detail the actual local magnetic field.

The alternative code method described above has a plurality of advantages in relation to the previously described angle code method. For instance all elements are arranged in parallel which means that the efficient bias field applied over a label is more limited or defined than in the angle coding method. Hereby the reading of the label is facilitated. A side effect is that all elements probably will be read through one and the same detecting channel which will reduce the distortion during transmission caused by detecting coils and detecting electronics.

The angle coding method and also the distance coding method described above can be utilized at mechanical resonance of the elements and detecting magnetic field changes as a result of the mechanical resonance, but also at electrical resonance, wherein the elements are included in electrical resonance circuits as magnetic elements coupled to the coil included in said resonance circuit.

CLAIMS

1. Method of remote sensing of objects including the steps of
marking said objects with at least one label (10) comprising at least one electrical resonance circuit (14) having an inductive element (11) and a capacitive element (12),
exciting said resonance circuit (14) to oscillation at at resonance frequency within the radio frequency interval, and
detecting the resonant frequency of the resonant circuit (14) through the electromagnetic energy transmitted from said resonant circuit (14), c h a r a c t e r i s e d by coupling inductively an element (13) of magnetic material having a varying permeability to said inductive element (11),
by affecting the resonant frequency of the resonant circuit through the permeability of the element (13) of magnetic material, and
by exposing said element (13) of magnetic material to an external and spatially heterogeneous magnetic bias field through which the permeability of said element (13) of magnetic material is controlled.

2. Method according to claim 1, c h a r a c t e r i s e d in
that the permeability of said element (13) of magnetic material controls the resonant frequency of a plurality of resonant circuits (14).

3. Method according to claim 1 or 2, c h a r a c t e - r i s e d in
that one element (13) of magnetic material is inductively coupled to inductive elements (11) of at least two electric resonant circuits.

4. A device for remote sensing of objects, each object being marked with at least one label (10) comprising at least one electric resonant circuit (14) having an

inductive element (11) and a capacitive element (12), said resonant circuit (14) being formed to be excited to oscillation at the resonant frequency within the radio frequence interval,

an electrical excitation means (15) being provided for producing an electromagnetic signal exciting said resonant circuit (14), and a detecting means (16) sensitive of electromagnetic radiation being provided for detecting electromagnetic radiation from said resonant circuit (14),

c h a r a c t e r i s e d in

that said resonant circuit (14) comprises an element (13) inductively coupled to said inductive element (11), said element (13) being formed of a magnetic material having a varying permeability for affecting the resonant frequency of said resonant circuit (14),

that a magnetic field generating means (18) is provided for generating in a interrogation zone a spatially heterogenous magnetic bias field by which the permeability of said element (13) of magnetic material is affected.

5. Device according to claim 4, c h a r a c t e r i s e d in

that said element elements (13) of magnetic material are mechanically anchored to prevent mechanical oscillation.

6. Device according to claim 4, c h a r a c t e r i s e d in

that said label (10) is provided with a combination of mechanically anchored and mechanically free elements (13) of magnetic material.

7. Device according to claim 4, c h a r a c t e r i s e d in

that said electric resonant circuit (14) comprises a plurality of elements (13) of magnetic material having different magnetic characteristics.

8. Device according to claim 4, c h a r a c t e r i s e d in

that said label (10) comprises a combination of resonant circuits (14) together forming an item code of the object.

9. Device according to claim 4, c h a r a c t e r i s e d in that said means (18) for generating a magnetic field is formed to generate an adjustably modulated signal for generating a modulated bias field.

10. Device according to claim 4, c h a r a c t e r i s e d in that said element (13) of magnetic material is made of an amorphous material.

11. Device according to any of claims 4-10, c h a r a c t e r i s e d in that said inductive element (11) and said magnetic element (13) are combined into a web like structure.

12. Method for determining in three dimensions the position and orientation of objects, the method including the steps of marking said objects with at least one label (10) comprising at least one electric resonant circuit (14) having an inductive element (11) and capacitive element (12),
exciting said resonant circuit (14) to oscillation at the resonant frequency within the radio frequency interval, and detecting the resonant frequency of the resonant circuit (14) by the electromagnetic energy transmitted from said resonant circuit (14), c h a r a c t e r i s e d in that an element (13) made of magnetic material of a varying permeability is inductively coupled to said inductive element (11),
that the resonant frequency of said resonant circuit (14) is controlled by the permeability of the element (13) made of magnetic material,
that said element (13) made of magnetic material is exposed to an external magnetic bias field which is known in all points with a desired resolution with regard to strength

and/or direction, through which bias field the permeability of said element (13) made of magnetic material is affected, and

that the resonant frequency detected and controlled by said magnetic bias field is utilized for determining the position and orientation.

13. Method of remote sensing of objects, each of which being provided with an element (15) made of a material, the characteristics thereof being influenced by a surrounding magnetic field, said elements being exposed to a magnetic field strength H, and detecting the influence of the field strength on the characteristics by receiving a signal of magnetic or electromagnetic radiation from said element (15), c h a r a c t e r i s e d in

that the magnetic field strength H is forced to vary according to a predetermined function,

that said received signal is compared to said predetermined function, and

that any parts of the received signal fulfiling a predetermined correlation with the predetermined function is used for the remote sensing of objects.

14. Method according to claim 13, c h a r a c t e - r i s e d in

that the predetermined function is a function varying in time with a certain frequency,

that said received signal is fed to a Phase Locked Loop PLL) comprising a voltage controlled oscillator and a phase detector, the output thereof controlling the frequency of the oscillator, the output signal of said phase detector being related to the frequency of the varying function when said loop has been locked to the received signal, and

that the output level of the phase detector is compared to a predetermined level corresponding to a certain frequency of the varying function, a correlation between the output

level and the predetermined level indicating that the received signal originates from a remotly detected element.

15. Method according to claim 14,
c h a r a c t e r i s e d in
that said magnetic field strength H is controlled to vary in time and
that a time varying part of the received signal is separated and used for the remote sensing.

16. Method for coding remotely detected gauges (10), at least two elements (13), the characteristics thereof being changed by an external magnetic field, being provided for forming said gauge (10), said gage (10) being exposed to a biasing magnetic field covering a detecting volume that is larger than the gauge, and detecting the characteristics of said element (13) changed by said magnetic field,
c h a r a c t e r i s e d in
that the element of each gauge (10) are oriented in predetermined mutual relationships for providing an identity of the gauge (10) determined by said relations,
that said elements are exposed to a sequence of different field distributions,
that the local field distribution of the biasing field over said gauge continuously is determined, and
that the mutual relation between the elements is determined in dependence of the orientation of each element in the local field distribution by comparing actual properties of the elements influenced by said magnetic field, and expected properties of elements arranged in predetermined relations to each other in the local field distribution.

17. Method according to claim 16, c h a r a c t e r i s e d in
that said elements (13) are made elongated, and
that said elemnts (13) are oriented in fixed mutual angle relations with regard to the longitudinal direction of said elements (13).

18. Method according to claim 16, c h a r a c t e - r i s e d in
that said elements (13) are made elongated, and
that said elements (13) are oriented with fixed mutual distances in a direction transverse to the longitudinal direction of said elements (13).

19. Method according to claim 16, c h a r a c t e - r i s e d in
that the orientation of the elements (13) is determined in relation to a reference element.

20. Method according to claim 19, c h a r a c t e - r i s e d in
that the local field distribution is determined by providing at least two reference elements on the gauge (10), said reference elements being located with a known mutual orientation.

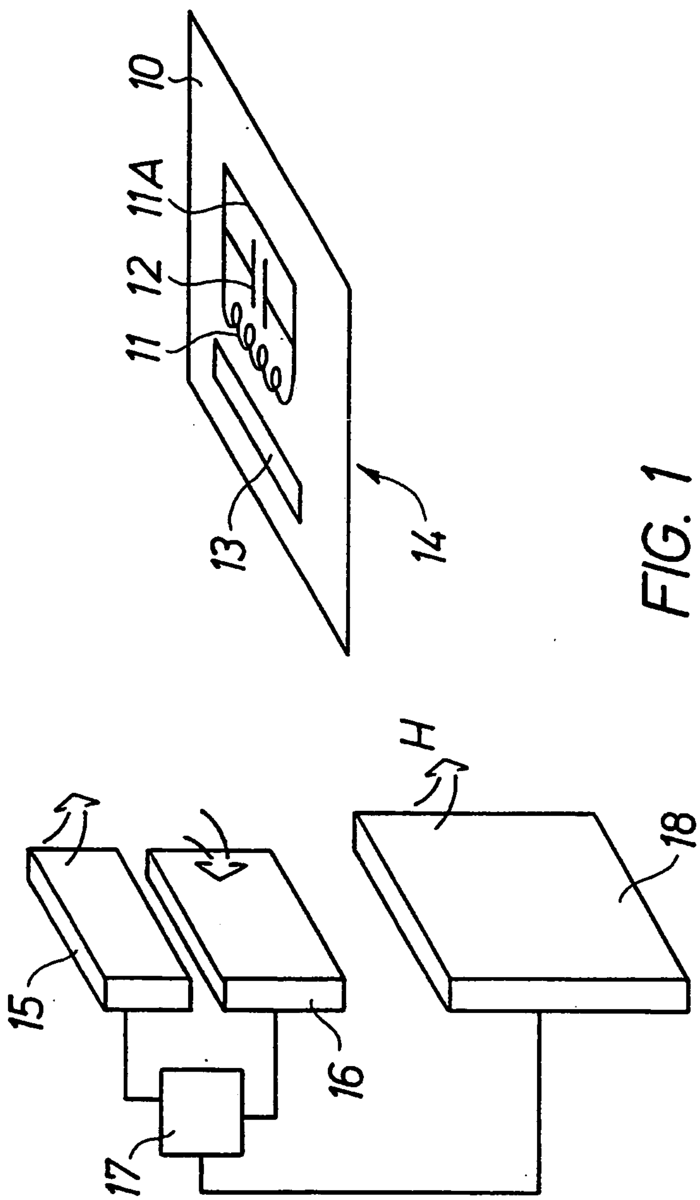


FIG. 1

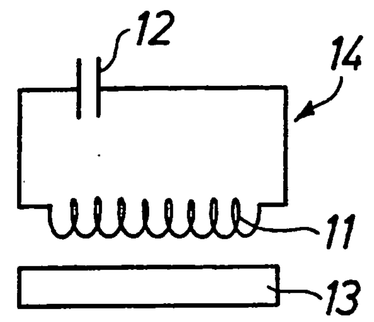


FIG. 2A

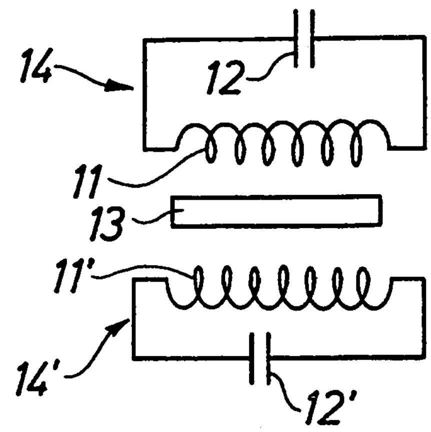


FIG. 2B

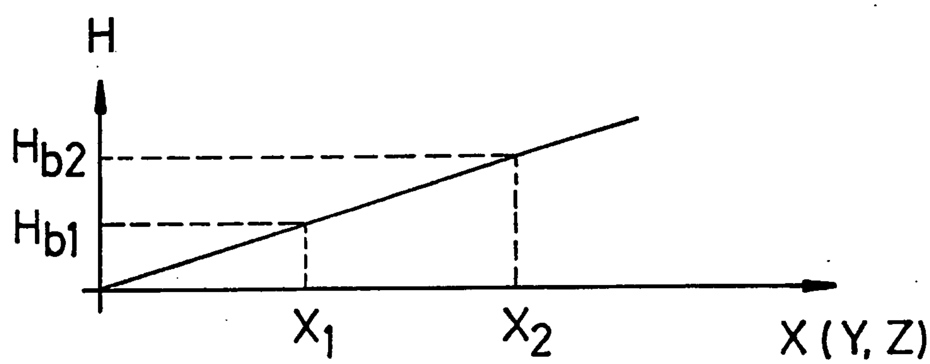


FIG. 3

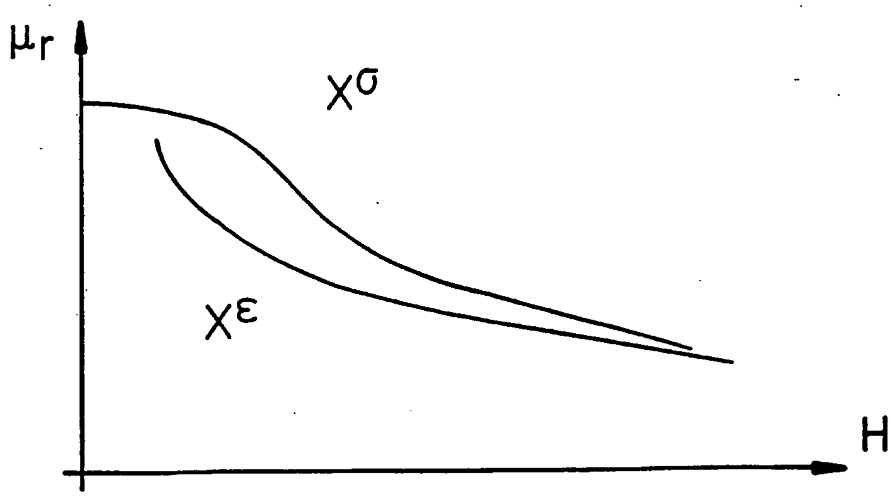


FIG. 4

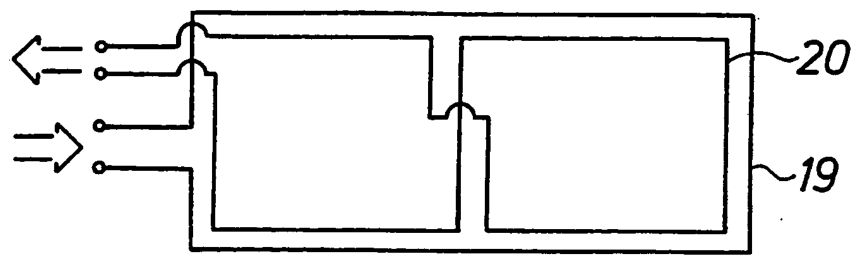


FIG. 5

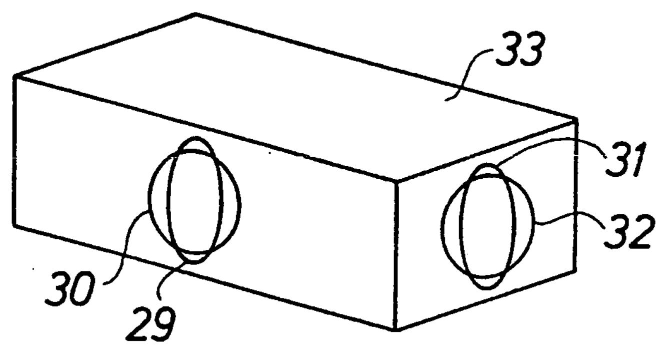


FIG. 7

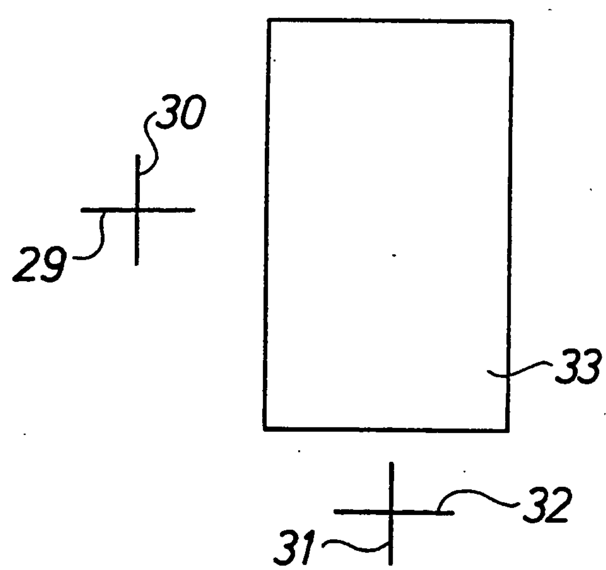


FIG. 8

SUBSTITUTE SHEET

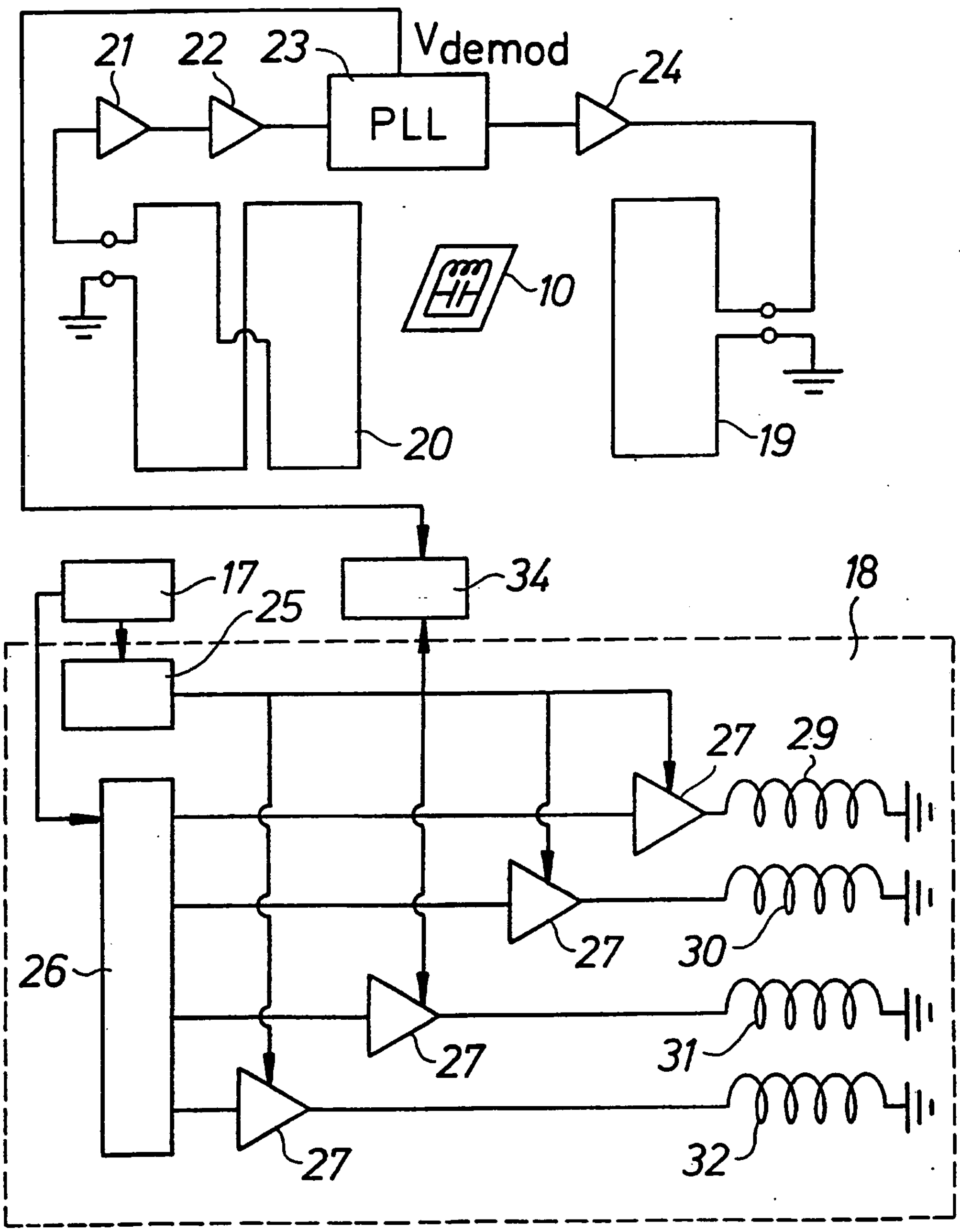


FIG. 6

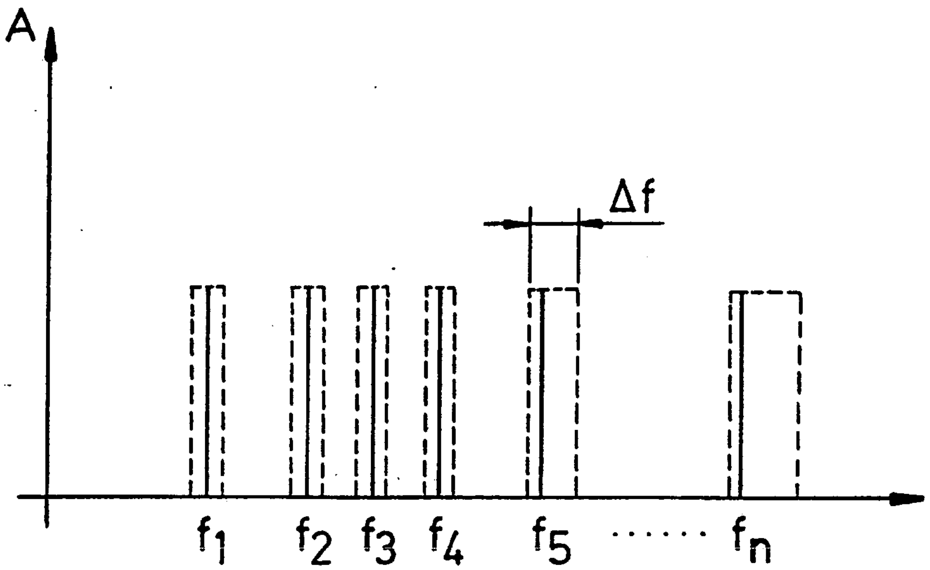


FIG. 9

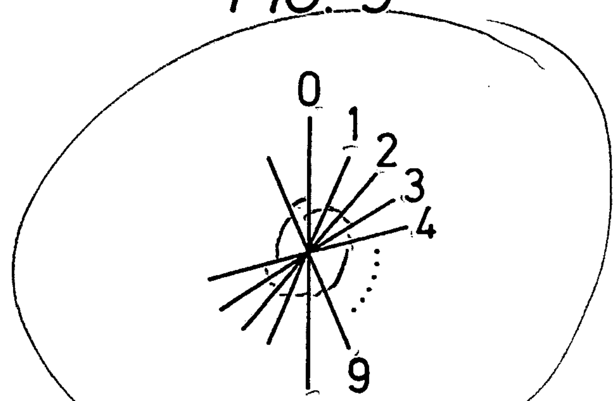


FIG. 10

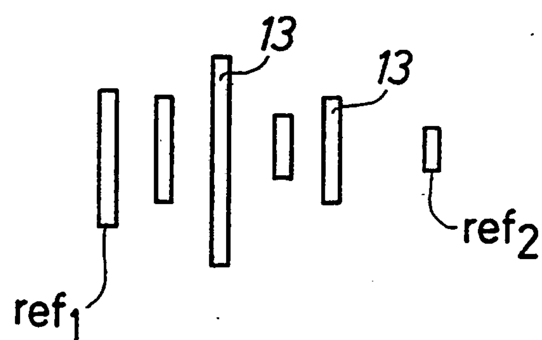


FIG. 11

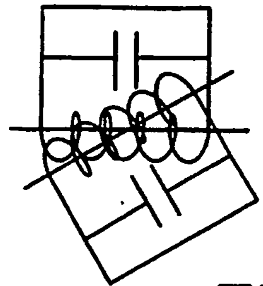


FIG. 12

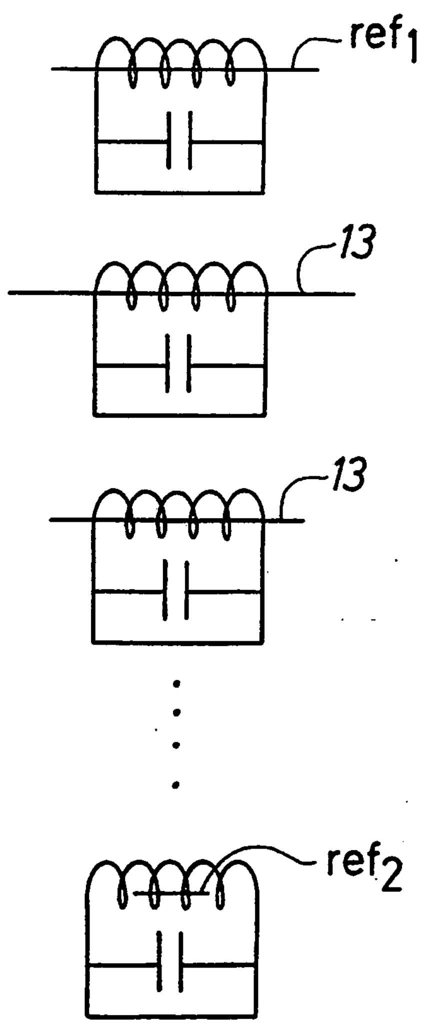


FIG. 13

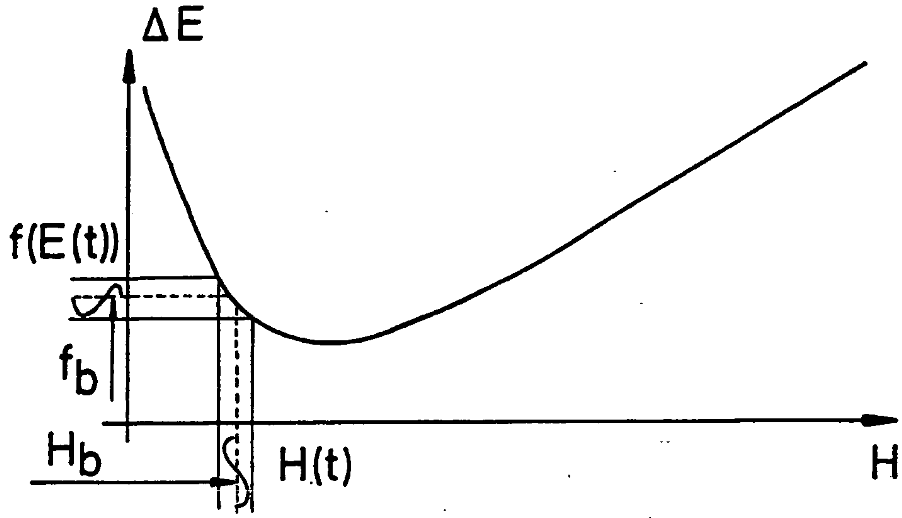


FIG. 14

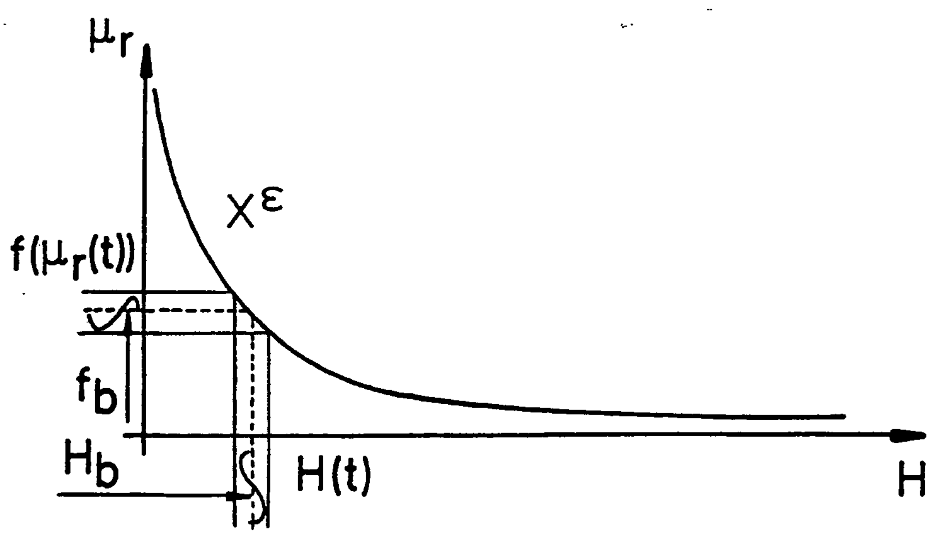


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 93/00036

A. CLASSIFICATION OF SUBJECT MATTER

IPC5: G08B 13/24, G01V 3/08, H04B 1/59, G01S 13/80, G07C 11/00, G06K 19/06, G01B 7/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC5: G01B, G01S, G01V, G06K, G07C, G08B, G11C, H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

ORBIT: WPAT DIALOG: INSPEC, WPI QUESTEL: EDOC, WPIL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO, A1, 8801427 (CARL H. TYREN ET AL), 25 February 1988 (25.02.88), page 4, line 13 - page 6, line 26, figures 1-7, claims 1-11, abstract --	1-20
A	WO, A1, 9100494 (CARL H. TYREN ET AL), 10 January 1991 (10.01.91), page 3, line 19 - line 28, figures 1-6, claims 1-10, abstract --	1-12
A	EP, A2, 0338696 (SECURITY TAG SYSTEMS INC.), 25 October 1989 (25.10.89), column 4, line 18 - line 31; column 5, line 11 - line 32, claims 1-2,5-8, abstract --	1,4,12,13,16

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" erlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 June 1993	14 -06- 1993
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Magnus Stiebe Telephone No. +46 8 782 25 00

WEST

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 93/00036

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4168496 (GEORGE J. LICHTBLAU), 18 Sept 1979 (18.09.79), abstract --	13
A	US, A, 4647917 (PHILIP M. ANDERSON, III ET AL), 3 March 1987 (03.03.87), column 1, line 47 - column 2, line 14, abstract --	13
A	EP, A2, 0366335 (THORN EMI PLC), 2 May 1990 (02.05.90), abstract -- --------	16

WEST

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 93/00036

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see next page.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

The application comprises three inventions:

1: Claims 1-12 define a first invention relating to a method and a device for remote sensing of objects, and also a method for determining the position and the orientation of objects in three dimensions. The objects are marked with at least one tag including an electric resonant circuit with an inductive and a capacitive element, and also an element of a magnetic material. The permeability of this material can be varied, and this element is inductively coupled to the inductive element. An external magnetic field controls the permeability of the material and thereby also the resonant frequency of the resonant circuit. This frequency is detected and used for the remote sensing of the objects, and for the determination of position and orientation.

2: Claims 13-15 define a second invention relating to a method for remote sensing of objects that are equipped with elements of a material whose characteristics are influenced by an external magnetic field. The elements are subjected to a magnetizing field strength (H), and the influence of the field strength on the characteristics is detected by sensing a signal. The magnetizing field strength is made to vary according to a predetermined function, and the sensed signal is compared with this function. Those parts of the signal that are in accordance with the predetermined function are used for the remote sensing.

3: Claims 16-20 define a third invention relating to a method for coding transponders which can be sensed remotely. At least two elements whose characteristics are influenced by an external magnetic field are oriented in predetermined positions relative to each other. These positions provide a transponder with an identity. The transponder is subjected to a biasing magnetic field and the changed characteristics of the elements influenced by the field are detected.

As the three inventions cited above do not present any common technical feature within the meaning of PCT Rule 13.2, second sentence, no technical relationship within the meaning of PCT Rule 13 can be seen between the different inventions.

INTERNATIONAL SEARCH REPORT
Information on patent family members

30/04/93

International application No.
PCT/SE 93/00036

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A1- 8801427	25/02/88	AU-A- 7806487	08/03/88
		CA-A- 1279386	22/01/91
		EP-A,B- 0330656	06/09/89
		SE-T3- 0330656	
WO-A1- 9100494	10/01/91	CA-A- 2062815	29/12/90
		EP-A- 0482120	29/04/92
EP-A2- 0338696	25/10/89	AU-B- 620085	13/02/92
		AU-A- 3306889	19/10/89
		JP-A- 1312488	18/12/89
US-A- 4168496	18/09/79	AU-B- 518385	01/10/81
		AU-A- 3947178	06/03/80
		CA-A- 1118865	23/02/82
		DE-A,C- 2843293	12/04/79
		FR-A,B- 2405527	04/05/79
		GB-A,B- 2005518	19/04/79
		JP-A- 54077600	21/06/79
		SE-B,C- 439703	24/06/85
		SE-A- 7810387	06/04/79
US-A- 4647917	03/03/87	JP-A- 60218223	31/10/85
EP-A2- 0366335	02/05/90	NONE	